Digital Screens and Pediatric Sleep Disruptions: Examining the Link Between Blue Light Exposure and Sleep Apnea in Children aged between (2-10)

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Abstract- ***The increasing use of digital screens among children has raised concerns about the effects of prolonged nighttime blue light exposure on sleep health. This study examines the potential relationship between extended exposure to blue light at night and the occurrence or severity of sleep apnea in children aged 2-10 years. Blue light, predominantly emitted by electronic devices, has been shown to suppress melatonin production and disrupt circadian rhythms, leading to poor sleep quality and potential respiratory disturbances. Given that sleep apnea is characterized by repeated episodes of upper airway obstruction during sleep, this study explores whether blue light exposure exacerbates its symptoms by interfering with natural sleep patterns and airway stability. Using a mixed-method approach, this research gathers data from parental surveys and expert interviews to assess sleep quality, apnea severity, and behavioral outcomes in children exposed to varying levels of blue light before bedtime. The study is grounded in the Circadian Rhythm Theory & Melatonin Suppression Hypothesis which collectively suggest that disrupted sleep cycles could influence respiratory stability during sleep. Findings from this study aim to contribute to pediatric sleep research and provide insights for parents, educators, and healthcare professionals in reducing potential risks associated with excessive nighttime screen exposure.***

Keywords: Blue Light Exposure, Sleep Apnea, Circadian Rhythms, Melatonin Suppression, Sleep Quality, Digital Screens

1.INTRODUCTION

The universal use of digital screens among children has raised concerns regarding the potential health effects of prolonged nighttime exposure to blue light. This concern is more after COVID-19 as the users' age has been seen more who are below 10 years. One of the critical areas of study is its impact on sleep disorders, particularly sleep apnea. Blue light exposure, especially before bedtime, has been linked to circadian rhythm disruption, melatonin suppression, and sleep disturbances. Understanding the interplay between blue light exposure and sleep apnea in young children is crucial for developing preventive strategies and guidelines for digital screen usage. Digital screens emit photons, specifically blue light, which can penetrate the eyes and affect neural functions. Blue light has a high-energy wavelength (380-500 nm) and has been shown to disrupt circadian rhythms, melatonin secretion, and brain activity. Prolonged nighttime exposure to blue light may lead to sleep disturbances, impaired cognitive development, and behavioral issues in young children. It's plausible that blue light exposure could indirectly influence sleep apnea symptoms by altering sleep architecture. However, more targeted research is needed to establish a direct connection between smartphone-emitted blue light and sleep apnea. There are several theories which support the objective of this research. These theories hold a strong point of view with regards to the relationship between Blue Light exposure before bedtime and Sleep disorders.

1. Circadian Rhythm Theory:

The Circadian Rhythm Theory explains how biological processes in humans and other organisms follow a 24-hour internal clock, regulating sleep, wakefulness, hormone release, body temperature, and other physiological functions. This internal clock, known as the circadian rhythm, is primarily controlled by the suprachiasmatic nucleus (SCN) in the

hypothalamus and is influenced by external cues, especially light exposure (Czeisler, C. A., & Gooley, J. J. 2007). Circadian Rhythm Theory gives insight about how exposure to short wavelength light, especially blue-light, contributes to sleep disturbance and ultimately other sleep disorders.

2. Melatonin Suppression Hypothesis: Mounting evidence from countries around the world shows the negative impact of such technology use on sleep. This negative impact on sleep may be due to the short-wavelength–enriched light emitted by these electronic devices, given that artificial-light exposure has been shown experimentally to produce alerting effects, suppress melatonin, and phase-shift the biological clock . (Chang, A. M. et al., 2015). Studies have shown an indirect relationship between digital screen usage and sleep disruptions due to low melatonin secretion which also causes dizziness throughout the day. This raises concern for the children below 10 years.

The purpose of this study is to examine the effects of prolonged nighttime blue light exposure on sleep patterns and its potential link to sleep apnea in children aged 2-10 years. The primary research question is regarding the screen time usage before bed and its indirect relation with Sleep Apnea. The purpose of this study is to find the link between the two variables. While previous studies have explored the effects of screen time on children's sleep, most focus primarily on screen duration, overlooking psychological factors such as bedtime behavior and perception of screen use. However, emerging research suggests that belief systems and emotional responses to screen exposure may play a critical role in shaping sleep outcomes (Cain & Gradisar, 2010; Hale & Guan, 2015). Given the increasing integration of screens in children's daily lives, this study aims to bridge the gap by investigating not only screen time, but also the delay in sleep and perceived impact of screen use. By doing so, it contributes to a more nuanced understanding of screen-related sleep disturbances, offering practical insights for parents, educators, and mental health professionals.

Significance of the Study: Understanding the impact of nighttime blue light exposure is essential for developing guidelines that promote healthy cognitive and behavioral development in children. This study aims to inform parents, educators, and policymakers about the potential risks associated with excessive screen time and provide evidence-based recommendations to mitigate these effects.

Hypothesis (H_0):

Null Hypothesis (H_0): "There is no significant relationship between prolonged nighttime blue light exposure and the occurrence or severity of Sleep Apnea in children aged 2-10 years when they are exposed to blue light before sleeping. Any observed variations in sleep apnea symptoms among children exposed to prolonged nighttime blue light are purely due to chance or other unrelated factors, rather than a direct impact of blue light exposure on sleep patterns, airway obstruction, or respiratory disturbances."

2.LITERATURE REVIEW

1. Blue Light and Sleep Disruption: Exposure to blue light during evening hours can suppress melatonin production, leading to delayed sleep onset and reduced sleep quality. This disruption in sleep patterns is particularly concerning for children, as adequate sleep is crucial for their development. Smartphones are often equipped with a light-emitting diodes (LED) display, which delivers bright light to the human eye. Smartphone LED light is an important source of 'Artificial Light At Night' (ALAN). ALAN influences the circadian regulation of the sleep-wake cycle (Gonzalez and Aston-Jones, 2006), suppresses melatonin secretion (Czeisler et al., 1995, Lewy et al., 1980), alters mood and cognitive functions (LeGates et al., 2012), and contributes to fatigue (Meesters and Lambers, 1990). Exposure to blue light LEDs of self-luminous tablets significantly reduced melatonin levels after 2hrs, compared to orange LED (Wood et al., 2013).

2. Blue Light Exposure and Melatonin Suppression: Melatonin is an endogenous hormone secreted from the pineal gland in the brain, and its secretion is known to be related to the regulation of circadian rhythm and the sleep/wake cycle (Sack et al. 2000; Cajochen et al. 2003; Arendt 2005). Light suppresses melatonin in humans, with the strongest response occurring in the short-wavelength portion of the spectrum between 446 and 477 nm that appears blue. Blue monochromatic light has also been shown to be more effective than longer-wavelength light for enhancing alertness.

Disturbed circadian rhythms and sleep loss have been described as risk factors for astronauts and NASA ground control workers, as well as civilians. Such disturbances can result in impaired alertness and diminished performance (Kathleen E West, 2011). Hormonal imbalancement of Melatonin leads to sleep disturbance and irregular sleep patterns which can be an indirect link between blue light exposure and sleep apnea. Blue light exposure, especially from digital screens in the evening, significantly suppresses melatonin production and delays sleep onset in children. Studies show that children are more sensitive than adults to these effects, leading to greater risk for sleep disturbances even after short exposure durations (Sleep Foundation, 2025; Higuchi et al., 2018; Silvani et al., 2022). Multiple systematic reviews and large-scale studies have confirmed a negative association between increased screen time and children's sleep outcomes. For each additional hour of daily screen use, sleep duration decreases and risks of difficulty falling asleep and night-wakings rise. These effects are especially pronounced with evening or bedtime screen use (Alsubhi et al., 2025; Hale & Guan, 2015; Gomes et al., 2024).

3. Association Between Blue Light Exposure and Sleep Apnea: Sleep apnea, a disorder characterized by repeated interruptions in breathing during sleep, has been increasingly observed in children with poor sleep hygiene and digital overuse. While Obstructive Sleep Apnea (OSA) in children is primarily linked to anatomical factors such as enlarged tonsils or adenoids, emerging research suggests that disrupted sleep patterns due to blue light exposure may exacerbate or contribute to sleep apnea symptoms. Children with excessive screen time before bed exhibited higher incidences of snoring, fragmented sleep, and daytime drowsiness, which are potential indicators of sleep-disordered breathing (Carter et al., 2016). Reading a book from an e-reader for four hours before sleep increased sleep onset latency, reduced evening sleepiness, melatonin secretion as well as next-morning alertness, and delayed the timing of the biological clock (Chang et al., 2015). Observational and cross-sectional studies internationally have identified a dose-dependent relationship between digital media use and pediatric sleep disturbances. Children with high screen time (more than 2–4 hours daily) exhibit up to a 25–35% increase in sleep onset latency and 20% reduction in total sleep time. These findings highlight screen time as a significant predictor for poorer sleep quality among young children (Kumari et al., 2024; Alsubhi et al., 2025). Blue light from digital devices affects circadian rhythms and sleep architecture. Research consistently finds that evening blue light exposure leads to increased sleep latency, decreased total sleep duration, and lower sleep efficiency, with children often being affected to a greater extent due to greater ocular sensitivity and developmental factors (Silvani et al., 2022; Viola et al., 2008; Ayaki et al., 2016).

4. Indirect Links to Sleep Apnea: While direct evidence connecting screen time to sleep apnea in children is sparse, the relationship between screen-induced sleep disturbances and factors that exacerbate sleep apnea is noteworthy. For instance, insufficient sleep has been associated with weight gain and obesity in children, which are known risk factors for Obstructive Sleep Apnea (OSA). Therefore, excessive screen time leading to poor sleep hygiene could indirectly increase the risk of developing OSA. Studies have identified links between poor sleep quality and reduced physical activity, greater recreational screen time, worse mental health, as well as increased/earlier substance use (Sampasa-Kanyinga et al, 2020). Given the strong bidirectional relationship between obesity and OSA (Tambalis et al., 2018), (Zucker, R. A., 2009).

Objectives:1. To analyze the relationship between blue light exposure before sleep and sleep apnea in children aged 2-10 years.

Operationalization of a Concept: While the term 'Sleep Apnea' was not used in the survey due to its medical complexity for a general audience, key symptoms and effects commonly associated with the condition were assessed. These included delays in falling asleep, frequent breathing problems, and perceived unrefreshing sleep. Thus, Sleep Problems in this study serve as proxy indicators for potential underlying sleep apnea. So by considering this, hereby Sleep Problems will be proxy indicator for Sleep Apnea.

3.RESEARCH DESIGN & RESEARCH METHODOLOGY

Research Design: This study adopts a correlational research design to examine the relationship between prolonged nighttime blue light exposure and sleep apnea in children aged 2-10. Study focuses on Negative Correlation between an Independent variable (Blue Light Screen time before) and a dependent variable (Sleep problems).

Research Methodology: This study employs quantitative analysis by survey of parents to understand the awareness about its effect on children. The expected sample size is 50-100 parents. The Survey was conducted among parents to get a random sampling by maintaining all confidentiality and following ethical considerations. The survey conducted was from different districts of Karnataka.

4.DATA COLLECTION

Data Collection:
1. Surveys & Questionnaires (Quantitative Research): A survey was conducted among parents to assess the screen time and sleep disturbance such as breathing problems while sleeping, interrupted sleep or other sleep problems. This survey targeted parents and guardians as they are best suited to give a reliable answer as their observation on their children is more precise.

Survey Questionnaires: The questionnaire framed were in English as well as Kannada which is the regional language of Kannada. Questionnaire were easy to read and easy to understand in both English and Kannada. The survey questionnaire consisted of Ten (10) questions designed to assess

Data Collection Tool: Google survey form was used to collect data for this research. Survey link was generated and shared via different social platforms.

Survey data: Survey data was collected for 2 weeks. Data contained 1 dependent and 1 independent variables. Collected data was transformed into Likert Scale. Below is the transformed data scale.

1. Independent Variable (IV) such as
a. Digital Screen Exposure at night time (measured in hours per day)

2. Dependent Variable (DV) such as
a. Sleep problem (breathing/ interrupted sleep/ watery eye).

3. Control Variables (CV) such as
a. Age of the child (2-10)
The questions included:

- Closed-ended questions to quantify opinions and behaviors.
- Likert scale items to measure attitudes or preferences on a scale from 1 to 10.

Statistical Tool:
Pearson Correlation Analysis is used to determine whether the variables [DV-Sleep problems/ Breathing Problem (one of the causes of Sleep Apnea)/ Watery eye)] has any relation with increase in [IV-Digital Screen Exposure at night time (in hours)].

5.DATA ANALYSIS

Data Analysis:
Quantitative Analysis:
The analysis of 56 survey responses for children (age 2–10) found that about 50% of children use mobile devices every night before bed, with nearly all reporting some screen use (Figure 1).

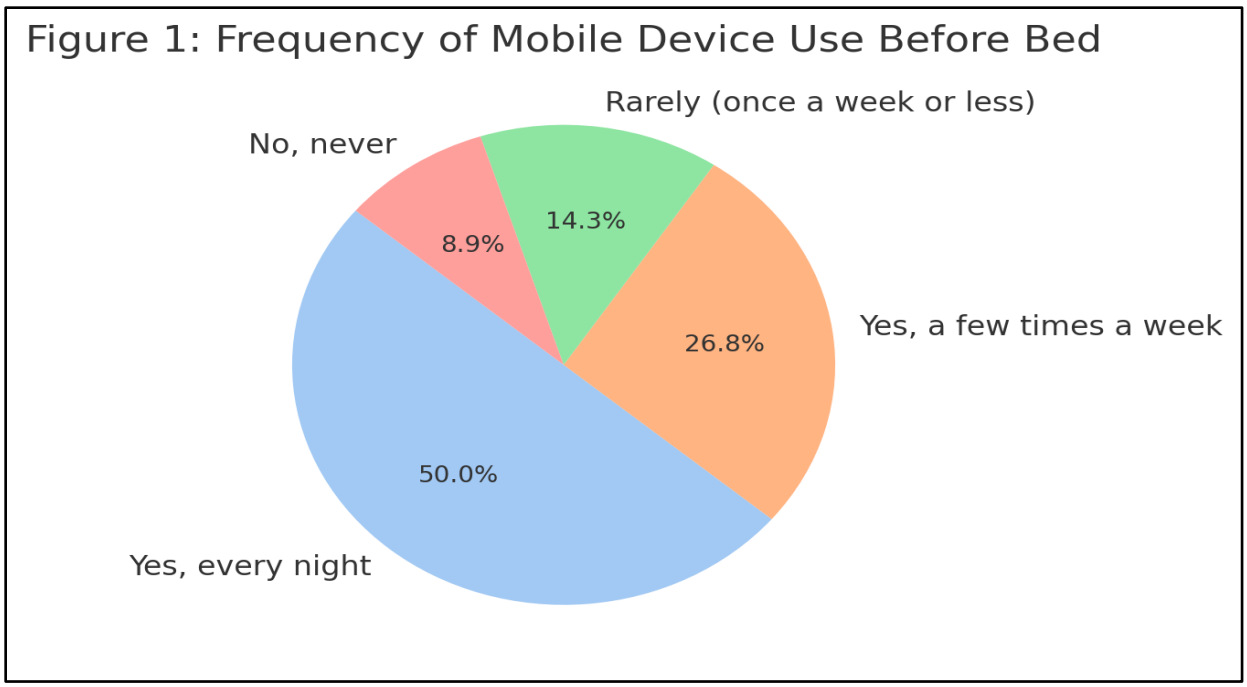


Figure 1: Frequency of Mobile usage before bed

The most common bedtime activities were watching cartoons/videos and using social media. Many caregivers reported sleep-related issues: e.g. ~36% noted that their child takes too long to fall asleep and others noted snoring or restless sleep (Figure 2)

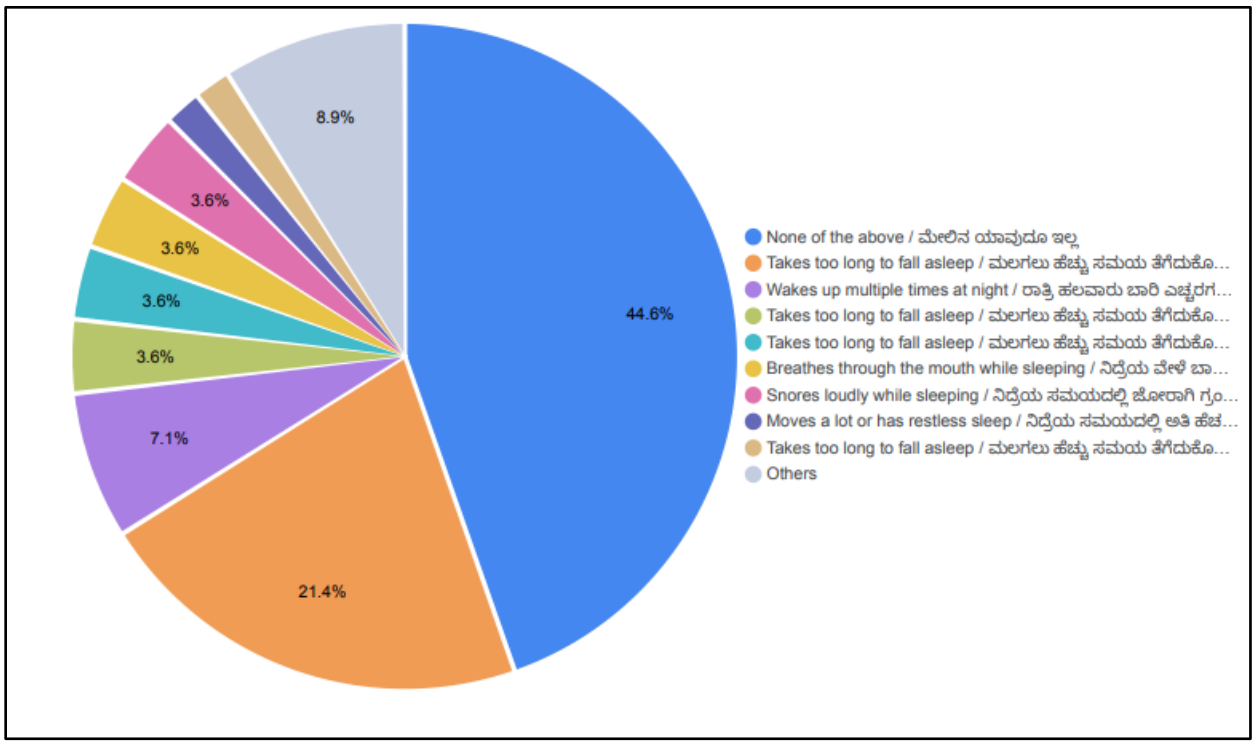


Figure 2: Sleep related problems

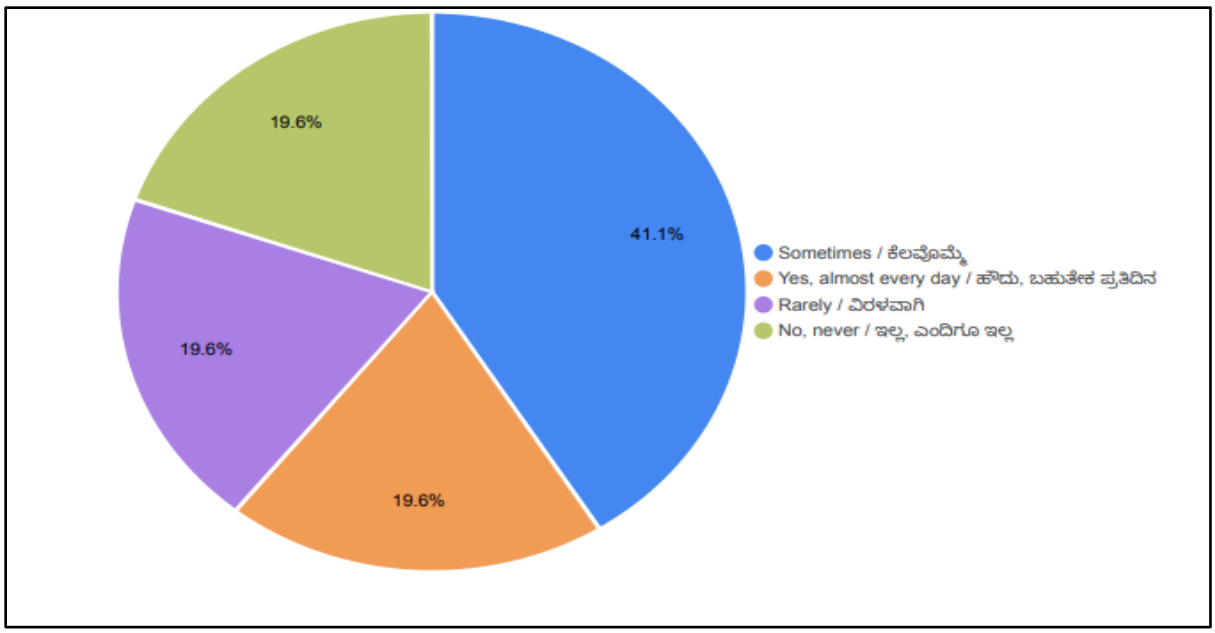


Figure 3: Daytime Sleepiness

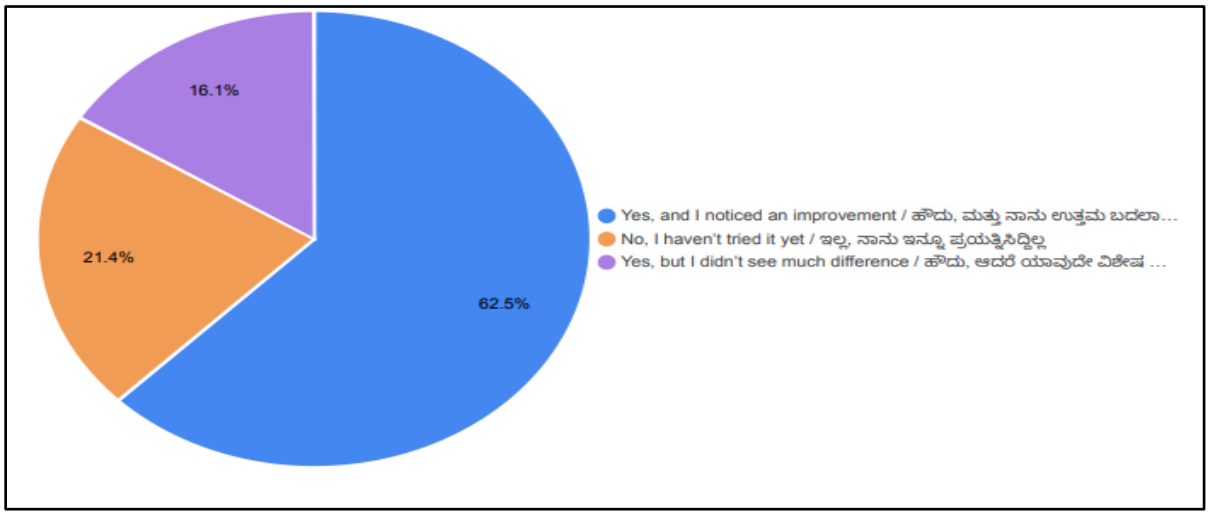


Figure 4: Effect of reducing screen time.

Hypotheses

Null hypothesis	Alternative hypothesis
There is no or a positive correlation between *Screen time Duration* and *Sleep Problems*	There is a negative correlation between *Sleep Problems* and *Screen time Duration*

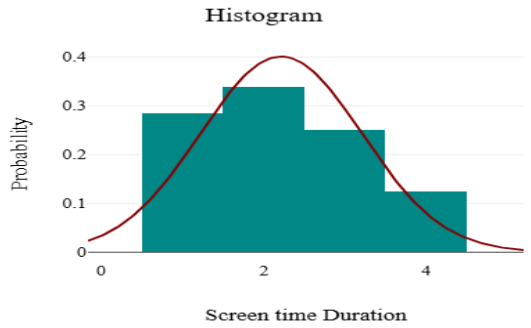
Pearson Correlation Analysis:

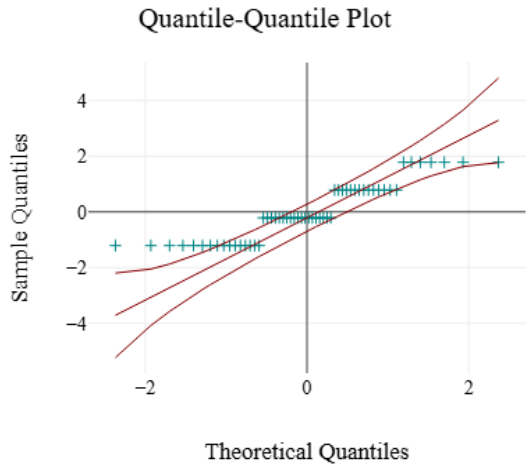
	Statistics	p
Kolmogorov-Smirnov	0.21	.012
Kolmogorov-Smirnov (Lilliefors Corr.)	0.21	<.001
Shapiro-Wilk	0.86	<.001
Anderson-Darling	2.77	<.001

Table 1: statistical test of Pearson Correlation Analysis

Interpretation:
Table 1 shows the results of four different statistical tests used to assess whether your data follows a normal distribution. A high p-value (greater than 0.05) suggests that the data does not significantly deviate from normality.

All four tests indicate that your data do deviate significantly from the normal distribution. This means that you should proceed with statistical methods that do not assume normality of the data. However, it is always a good idea to take a closer look at the QQ plot.





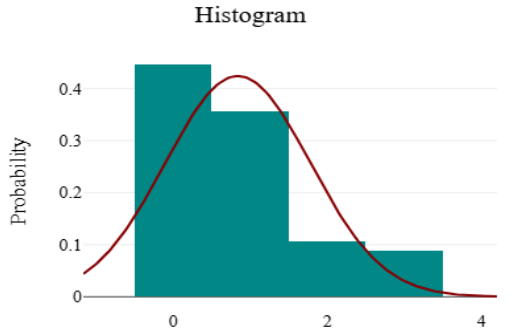
Tests for normal distribution of Sleep Problems:

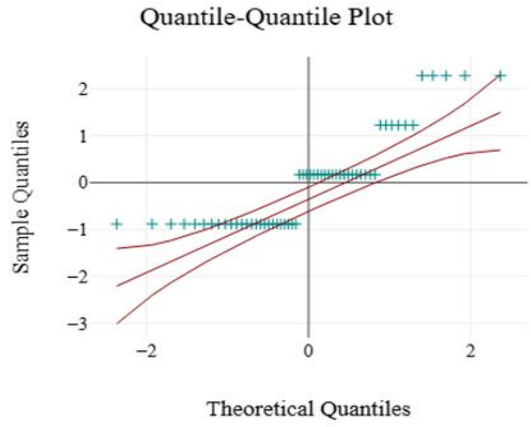
	Statistics	p
Kolmogorov-Smirnov	0.26	.001
Kolmogorov-Smirnov (Lilliefors Corr.)	0.26	<.001
Shapiro-Wilk	0.79	<.001
Anderson-Darling	4.56	<.001

Table 2: statistical test of normal distribution of Sleep Problems

Interpretation:
Table 2 shows the results of four different statistical tests used to assess whether your data follows a normal distribution. A high p-value (greater than 0.05) suggests that the data does not significantly deviate from normality.

All four tests indicate that your data do deviate significantly from the normal distribution. This means that you should proceed with statistical methods that do not assume normality of the data. However, it is always a good idea to take a closer look at the QQ plot.





Valid Cases:

	Valid cases
Number	56

Correlation:

	r	p
Screen time Duration and Sleep Problems	-0.02	.441

Table 3: summary of the correlation analysis for the variables Screen time Duration and Sleep Problems

Interpretation:

Table 3 summarises the results of the correlation analysis for the variables *Screen time Duration* and *Sleep Problems*, showing the correlation coefficient (r) and the p-value (p).

Correlation Coefficient:

The correlation coefficient indicates the strength and direction of the linear relationship between *Screen time Duration* and *Sleep Problems*. The coefficient -0.02 suggests a negligible, negative correlation. This means that, generally, as *Screen time Duration* increases, *Sleep Problems* tend to decrease and vice versa.

It's important to note that correlation does not imply causation, meaning that we cannot conclude from this result whether one variable influences or causes changes in the other.

p-Value:

The p-value is used to assess whether the available data provide sufficient evidence to reject the null hypothesis. In this case, a one-sided hypothesis is tested and the null hypothesis states that there is no or a positive correlation between *Screen time Duration* and *Sleep Problems* in the population (and the alternative hypothesis states that there is a negative correlation). In most cases, a p-value of less than 0.05 is considered statistically significant. In this case, the p-value of .441 is greater than 0.05. The null hypothesis that there is no or a positive correlation between *Screen time Duration* and *Sleep Problems* in the population is therefore not rejected. The result of the Pearson correlation thus showed that there was no statistically significant negative correlation between *Screen time Duration* and *Sleep Problems*, $r(54) = -0.02$, $p = .441$.

Strength of correlation:

Amount of r	Strength of the correlation
0.0 < 0.1	no correlation
0.1 < 0.3	low correlation
0.3 < 0.5	medium correlation
0.5 < 0.7	high correlation
0.7 < 1	very high correlation

Discussion: The correlation analysis in this study revealed that screen time duration has a negligible and statistically non-significant negative relationship with sleep problems ($r = -0.02$, $p = .441$). This suggests that longer or shorter screen use alone does not significantly influence sleep disturbances in children. This finding aligns with previous research by Przybylski (2019), which showed that screen time explains very little variance in well-being, including sleep outcomes.

However, the study found a strong and significant positive correlation between delays in falling asleep and the belief that screen use negatively affects sleep (Spearman's $\rho = 0.601$, $p < .001$). These results support the idea that psychological factors and bedtime behavior play a more crucial role than screen duration alone in predicting sleep disturbances (Cain & Gradisar, 2010; Hale & Guan, 2015).

Implication: Educators, counselors, and parents should shift their focus from merely reducing screen time to understanding how screen use interacts with children's sleep behavior and beliefs, in order to promote healthier sleep patterns. Future research should further investigate underlying psychological factors and media content type to provide clearer guidelines for managing screen exposure in children.

6.RESULT & CONCLUSION

Result:

The result of the Pearson correlation showed that there was a negligible, negative correlation between *Screen time Duration* and *Sleep Problems*. The results showed that this correlation between *Screen time Duration* and *Sleep Problems* was not a statistically significant negative correlation, $r(54) = -0.02$, $p = .441$. Hence, the Null Hypothesis is proved.

Conclusion:

The findings from the Pearson correlation analysis indicate that there is a negligible and statistically non-significant negative correlation between screen time duration and sleep problems in children. With a correlation coefficient of $r(54) = -0.02$, $p = .441$, the results suggest that increased or decreased screen time alone is not directly associated with the presence or severity of sleep-related issues.

This implies that while screen time is often discussed in relation to children's sleep health, it may not independently predict sleep problems without considering other moderating factors such as bedtime routines, emotional regulation, content type, or perceived screen impact. Therefore, future research should explore multi-variable models or interaction effects that may better capture the complexity of screen use and its relationship with child sleep outcomes.

Key Findings:

- Device Use Before Sleep: The pie chart shows that half of children use a phone/tablet *every night* before bedtime, 27% use it a few times per week, 14% use it rarely, and only 9% never use devices before sleep (Figure 1). (This trend suggests ubiquitous bedtime screen exposure.)
- Screen Cessation Timing: Only 25% of children stopped all screens more than 1 hour before bed; the majority stopped within 30 minutes of bedtime. This indicates that most device use extends very close to sleep time.
- Reported Sleep Problems: Many caregivers observed issues. In total, 31 children (55%) had at least one reported sleep problem (Figure 2), while 25 children (45%) had no problems. The most frequent issue was "takes too long to fall asleep" (20 reports, ~36%), followed by night wakings (9 reports, 16%) and restless sleep/movements (8 reports, 14%). Snoring and mouth-breathing were each noted in ~11% of children. These counts are shown in Figure 3.
- Daytime Sleepiness: When asked about daytime tiredness, 23 caregivers (41%) said sometimes, and 11 (20%) said almost every day; the rest said rarely or never. This suggests that a significant fraction of children show daytime sleepiness (Figure 3), which may correlate with night sleep quality.
- Parental Perception: A majority (62%) *strongly felt* screen use affected sleep, 27% were unsure, and 11% saw no effect (Figure 5). Likewise, 57% were *fully aware* of blue-light effects on melatonin, 27% somewhat aware, and 16% unaware (Figure 6). Notably, 62% of parents had tried reducing screen time and *noticed improvement* in sleep, while ~16% tried with no change and 22% had not tried yet (Figure 4). Almost all parents (88%) said they would definitely or probably change habits if it helped sleep.
- Patterns in Data: Overall, those children who frequently used devices tended to have more reported issues (e.g. of the 28 "every night" users, 18 had at least one sleep problem). However, even among non-users, some had problems, and vice versa. Figure 3 summarizes all problems by category, and suggests that no single issue dominates except "difficulty falling asleep".

7.DECLARATION

This is to certify that the project titled 'DIGITAL SCREENS AND PEDIATRIC SLEEP DISRUPTIONS: EXAMINING THE LINK BETWEEN BLUE LIGHT EXPOSURE AND SLEEP APNEA IN CHILDREN' is carried out independently by me under the guidance of Assistant Professor Dhruthi S Prasad. This work is an original one and has not been submitted earlier to any University or any other Institution for the fulfillment of the requirement of course study or any other credential.

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